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Intraoperative Transcranial Doppler Sonography Monitoring during Carotid Surgery under Locoregional Anaesthesia

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Objectives: *Studies comparing transcranial Doppler ultrasonography (TCD) with other intraoperative monitoring techniques for detecting clamping ischaemia during carotid endarterectomy under general anaesthesia suggest that a reduction of > two-thirds in the mean middle cerebral artery velocity (mMCAv) or a reduction of > 0.4 in the pre-clamping mMCAv: clamping mMCAv ratio warrants cerebral protection. Our aim was to study the relationship between mMCAvs and clamping ischaemia during carotid endarterectomy in awake patients.*

Materials and methods: *In a consecutive series of 57 patients undergoing carotid endarterectomy under locoregional anaesthesia 51 were monitored by intraoperative TCD, continuous EEG, and neurologic awake testing.*

Results: *Five of the 51 (9.8%) patients had transient clamping ischaemia, which carotid shunting reversed. TCD showed that these five patients had significant lower mean mMCAvs than the other 46 patients, who had no deficits (1.8 ± 1.1 cm/s vs. 26.2 ± 8.5, p = 0.0003). Current TCD criteria indicated that four other patients (7.8%) should have been shunted. All four had significantly higher clamping mMCAvs than the five shunted patients (11.5 ± 1.9 vs. 1.8 ± 1.1, p = 0.0012).*

Conclusions: *Intraoperative TCD detected cerebral ischaemia and yielded no false-negative. An mMCAv of 10 cm/s or less may indicate the risk of clamping ischaemia better than the higher threshold currently proposed. This would avoid unnecessary shunting due to false-positives.*

Introduction

Various techniques have been proposed for intraoperative cerebral monitoring during carotid endarterectomy to identify patients who do not tolerate carotid clamping and require cerebral protection. These include measurements of carotid stump pressure,[1,2] regional cerebral blood flow (rCBF) evaluation by 133 Xenon,[3,4] intraoperative electroencephalography (EEG)[5,6] and somatosensory-evoked potentials (SEPs).[7]

In 1982 Aaslid *et al.* first applied transcranial Doppler ultrasonography (TCD)[8] for the diagnosis and monitoring of cerebral vasospasm in patients with subarachnoid haemorrhage. Since then this technique has been widely used in the diagnosis of cerebrovascular disease. More recently, TCD has been used for intraoperative monitoring of mean middle cerebral artery blood flow velocity (mMCAv) to detect clamping ischaemia in patients undergoing carotid endarterectomy under general anaesthesia. In patients who have a temporal bone window this technique is as accurate as the other intraoperative monitoring devices currently used.[9,10] Recent studies designed to determine the mMCAv needed to protect the brain from cerebral clamping ischaemia during carotid endarterectomy[11–13] have reported that a > two-thirds decrease in the pre-clamping mMCAv or a ratio between the pre-clamping and clamping mMCAv of < 0.4 indicate the need for a shunt. In determining these criteria, TCD mMCAv findings were compared with data from the monitoring techniques listed above, in patients receiving general anaesthesia. Yet studies comparing indexes determined in patients under general anaesthesia with indexes referring to the onset of neurologic deficits during carotid clamping in awake patients under locoregional anaesthesia clearly show that even highly sophisticated monitoring techniques result in false-positive and false-negative detections for clamping ischaemia.[14,15]

Our aim in this paper was to study intraoperative TCD blood-flow velocity data recorded during carotid

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endarterectomy in patients under locoregional anaesthesia. In particular, we evaluated the blood-flow velocity changes induced by carotid artery clamping. We then determined whether the onset of neurological dysfunction in awake patients confirmed current TCD criteria for assessing the risk of clamping ischaemia.

Materials and Methods

Between November 1993 and September 1994, a consecutive series of 57 patients underwent carotid endarterectomy under locoregional anaesthesia. Five of 57 patients (8.7%) had no temporal window and in one awake patient movement caused the interruption of perioperative TCD monitoring. Fifty-one patients were therefore available for study. They were 45 men and six women, mean age 59 years, range 55–75 years. Thirty-eight of the 51 patients (74.5%) had transient ischaemic attacks, 13 (25.5%) had asymptomatic severe (> 80%) internal carotid artery stenosis. The incidences of the risk factors for atherosclerotic disease and the associated vascular diseases are reported in Table 1. All patients had neurologic evaluation before surgery. Duplex scanning and four vessel angiography by the Seldinger technique were used to define the site and severity of carotid artery lesions: 17 patients (33.3%) had unilateral internal carotid artery stenosis, 23 (45%) bilateral stenosis and 11(21.6%) stenosis and contralateral occlusion. Forty-three patients (84%) also underwent contrast-enhanced brain CT scans.

For surgery all patients received locoregional anaesthesia by cervical block induced by injecting 18 mg of 0.25% bupivacaine hydrocloride into cervical roots C2, C3 and C4, then injecting 2% lignocaine hydrocloride subcutaneously along the skin incision. Patients who developed loss of consciousness or a contralateral motor deficit after carotid cross clamping underwent selective shunting. Intraoperative monitoring, including continuous quantitative electroencephalographic recording (QEEG, by ABM Datex), ensured an alternative monitoring technique in case the operation had to be converted from locoregional to general anaesthesia.

Table 1. Risk factors for atherosclerotic disease and associated vascular disease in the 51 patients undergoing carotid endarterectomy under locoregional anaesthesia.

Risk factors		Associated vascular disease	
Hypertension	69%	Coronary artery disease	20%
Diabetes	12%	Occlusive disease lower limb	33%
Hypercholesterolaemia	59%	Abdominal aortic aneurysm	6%

During surgery, systemic arterial blood pressure was continuously and invasively monitored to assess the steady haemodynamic state. Intraoperative mMCA velocities on the side of the operation were continuously recorded by TCD (EME TC2 64 Carolina Medical Electronics) according to the technique described by Aaslid *et al.* for insonnation of the middle cerebral artery.[8]

On completion of carotid artery dissection the patient received an intravenous injection of heparin (1 mg/kg) and cerebral function was assessed with a 1 min clamping test. The onset of a contralateral neurologic deficit or loss of consciousness was the indication for insertion of an intraluminal indwelling Sundt shunt between the common and internal carotid arteries. The TCD mMCA velocities recorded at clamping and the neurologic status were compared. In all patients, the analysis evaluated possible discordance between these values and the currently reported criteria for shunting in general anaesthesia (decrease of > two-thirds in the mMCAv, or pre-clamping: clamping mMCAv ratio > 0.4). Data were stored in a database and analysed for statistical significance by State View TM II with descriptive (mean and standard deviation) and comparative parametric tests (Two tailed Student's *t*-test).

Results

Continuous TCD monitoring of blood flow velocities in the 51 patients undergoing carotid endarterectomy under locoregional anaesthesia showed that the mMCAv recorded before common and external carotid artery clamping was almost twice as high as that after clamping (45.4 ± 15.8 cm/s vs. 23.7 ± 11.1 cm/s, min 0 max 44). Patients in whom neurological deficits developed after clamping had an mMCAv less than or equal to 10 cm/s; those in whom neurological deficits did not develop had an mMCAv higher than 10 cm/s (Fig. 1). The clamping test induced neurological deficit in five (9.8%) of the 51 patients. These five subjects had a low mMCAv (1.8 ± 1.1, min 0 max 3). (Fig. 2) In one other patient the onset of a neurological deficit during the clamping test coincided with a mean arterial blood pressure of 100 mmHg and a mean MCAv of 10 cm/s. Increasing the blood pressure by 20 mmHg resolved neurological deficit and the mean MCAv increased to 12 cm/s. This patient underwent endarterectomy without shunting and without neurologic complications.

In the five patients with neurological dysfunction at the clamping test, shunting reversed the deficit.

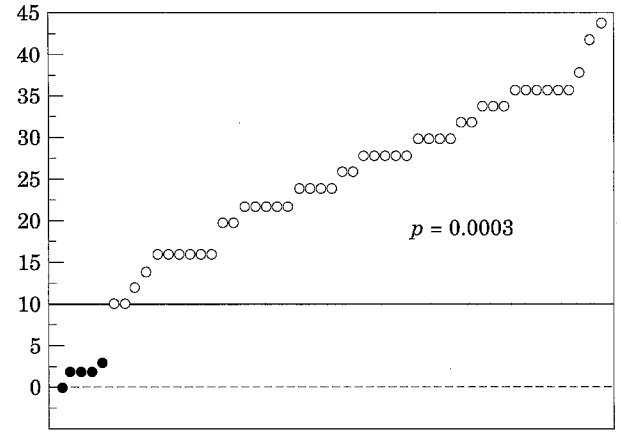

Fig. 1. Clamping test: mean MCAv. Fifty-one patients distribution. Intraoperative mMCAv recorded during operation and the relationship with neurological status after clamping test. (●) clamping ischaemia; (○) tolerance for clamping.

Continuous TCD monitoring showed that the 46 patients who tolerated carotid artery clamping had significantly higher mMCA velocities than the five patients who did not (26.2 ± 8.5 cm/s vs. 1.8 ± 1.1 cm/s, $p = 0.0003$ by two-tailed Student's *t*-test) (Fig. 2). According to the currently used intraoperative TCD criteria for shunting four other patients (7.8%) in whom neurologic dysfunction did not develop should have been shunted. These four patients had a significantly higher clamping mMCAv than the five patients who did not tolerate clamping (11.5 ± 1.9 cm/s vs. 1.8 ± 1.1 cm/s, $p = 0.0012$ by two-tailed Student's *t*-test) (Fig. 3), showing that the risk of clamping ischaemia differed significantly in these two subgroups. None of the patients in this small series sustained perioperative neurological complications and no patients died.

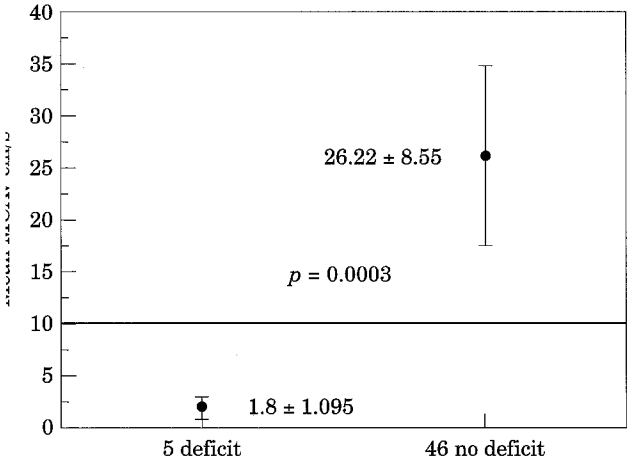

Fig. 2. Clamping test: mean MCAv. Fifty-one patients. Comparison between mMCAv (S.D.) of the patients with and without ischaemia at clamping test.

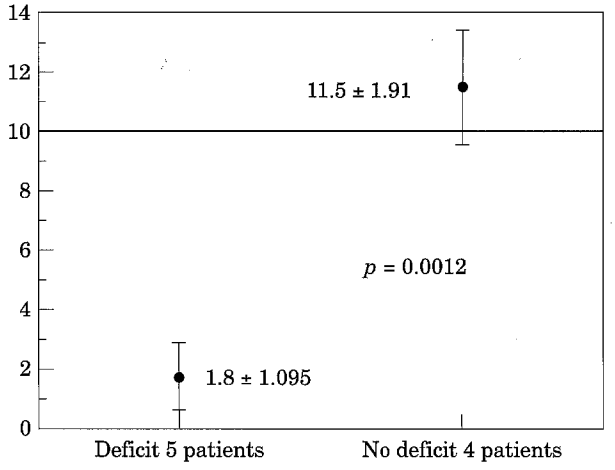

Fig. 3. Clamping test: mean MCAv. Nine patients with >2/3 mean MCAv decrease. Difference between velocity of the two subgroups of patients with >2/3 mMCAv decrease during clamping was statistically significant. (Student two tailed *t*-test).

Discussion

Carotid endarterectomy in awake patients under locoregional anaesthesia is generally accepted as the best method for detecting the onset of clamping ischaemia.[16,17] Comparative studies correlating findings from awake neurologic testing during locoregional anaesthesia with data from instrumental monitoring techniques (Stump pressure, EEG, SSEPS, and rCBF) have shown that all these techniques give rise to false-positive and false-negative detections.[14,15,18] Yet many vascular surgeons still prefer to do endarterectomies under general anaesthesia, probably because it is more simple and less traumatic for surgeons patients alike. Because some anaesthetic gases used for general anaesthesia increase cerebral blood flow, general anaesthesia also provides brain protection. An additional advantage is that under general anaesthesia cerebral perfusion can easily be increased further by increasing the partial pressure of carbon dioxide.[19–21] For these reasons most studies investigating TCD as a technique for monitoring neurological function by mMCAv during carotid endarterectomy refer to general anaesthesia.[9–13]

The reported decrease in mMCAv after carotid clamping differs according to the monitoring techniques studied. Comparing rCBF measurements with mMCAvs in patients with high cerebral blood flow levels. Halsey *et al* .[22] concluded that the results did not correlate. In a later study they concluded that they correlated at an rCBF of < 20 ml/100 g min. EEG findings positive for clamping ischaemia corresponded to an rCBF of 9 ml/100 g min and to an mMCAv of 15 cm/s.[23] Pedayachee *et al.*[9] and Naylor *et*

al.[11] found a good correlation between mMCAvs and stump pressure: a stump pressure of < 50 mmHg corresponding to a mMCAv < 30 cm/s. Although the reliability of TCD and EEG for detecting cerebral ischaemia during carotid surgery remains unconfirmed, Jansen *et al.*[24] reported that the use of the two techniques in conjunction improved detection. Some patients in their series had normal EEG findings despite abnormally low mMCAvs, others had abnormal EEG yet normal mMCAvs. Schneider *et al.*[10] recorded EEG changes in four patients who had an mMCAv of 14.7 ± 8.5 cm/s. These discrepancies support Halsey *et al*'s conclusion that the mean blood flow velocity corresponding to major EEG changes varies too widely to allow precise correlation.

In patients undergoing carotid endarterectomy under general anaesthesia many variables — notably end-tidal Pa CO2 and the type of anaesthetic used to maintain anaesthesia — also interfere with intracranial vascular resistances and cerebral blood flow, thus making it difficult to identify an absolute mMCAv. Hence, a more reliable indicator of clamping ischaemia has proved to be the ratio between the pre-clamping and clamping mMCAv. Most investigators agree that a decrease of more than two-thirds in clamping mMCAv compared to pre-clamping value or a clamping mMCAv : pre-clamping mMCAv ratio > 0.4 are satisfactory criteria for identifying patients needing cerebral protection and shunting during carotid endarterectomy under general anaesthesia.[10,22,25,26]

In this study, investigating patients mMCAvs recorded during carotid endarterectomy and comparing the onset of a neurological deficit or loss of consciousness in awake patients, only five of the 51 patients (9.8%) needed shunting. In all five clamping recordings showed a highly significant fall in the mMCAv. If we had applied the currently reported TCD criteria, another four patients would have been shunted. None of these four patients had clamping-induced neurologic deficits. In addition, at cross clamping they had a significantly higher mMCAv than the five shunted patients, showing that the risk of clamping ischaemia differed between the two subgroups. This suggests that the proposed safe limits include patients not at risk of clamping ischaemia during carotid endarterectomy (false-positive results). As well as increasing the risk of complications related to the shunt (twisting, embolisation, thrombosis or dissection of the internal carotid artery), unwarranted shunting would also have added unnecessary risks due to the more troublesome operative procedures that shunts entail. Despite being infrequent, shunt-related events are widely reported in literature and account for an estimated 0.5% of all intraoperative complications with the most qualified centres currently reporting an overall perioperative complication rate of about 2%.[27–29]

In conclusion, our comparison between TCD monitoring the observed onset of neurologic deficits in patients operated under locoregional anaesthesia may help to define a new, lower critical level of mMCAv. Patients with mMCAv velocities equal or less than 10 cm/s need cerebral protection with an internal carotid artery shunt.

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